Motion Detection for Home Security with Visible Light Communication

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***Abstract*— Visible Light Communication (VLC) is a technology that is fast becoming the alternative choice for wireless communication technologies. The technology uses light emitting diodes (LEDs) for both illumination and communication purposes. Current security systems use motion detection with infrared communication and/or camera technology. These systems are well known amongst intruders, making them vulnerable to tampering and even hacking. In this paper we present how can visible light technology can be used to detect any kind of motion and send an alarm to prevent any suspicion activity.**

Keywords- visible light communication; LED; phototransistor; Arduino; on-off-keying modulation.

I. INTRODUCTION

Visible Light Communication (VLC) is a technology that is fast becoming the alternative choice for wireless communication technologies [1]. The technology uses the visible light spectrum to transmit data at low cost and at the advantage of an unregulated bandwidth. The technology uses light emitting diodes (LEDs) for both illumination and communication purposes. Current security systems use motion detection with infrared communication and/or camera technology. These systems are well known amongst intruders, making them vulnerable to tampering and even hacking. With VLC, light does not penetrate through walls, this is an advantage because hacking and eavesdropping can be prevented. Another advantage is that, this technology is innovative and unfamiliar amongst intruders. The system uses an LED and a phototransistor for communication, the LED forms part of the transmitter and the phototransistor forms part of the receiver. The LED will be modulated at high frequencies in a way that the human eye cannot perceive its on-off switching, in that manner it appears as a constant light beam.

LEDs are used in this technology because of their beneficial characteristics, such as fast switching capabilities and the ability to modulate their current intensities [2]. The LEDs were built with the use of illumination and high-speed data transmission. Certain modulating schemes modulate the diodes' intensity to achieve a goal for data transmission for VLC. The intensity is modulated in such a way that the human eye is unable to perceive the on-off switching of the light, this is important because the ability of the light to illuminate is not compromised [3].

Currently, radio frequency communication is being used the most amongst others. Wi-Fi uses radio frequencies, it is used daily to send data around the world. Wi-Fi is used to browse the internet, to send images from a camera to a personal computer or to send images through social media from one phone to another, to name a few applications. Recently Wi-Fi is used to communicate with printers. It is evident that this technology has become more popular amongst others, but it is not without its limitations. Its bandwidth of up to 100 Megabits per second (Mbps) does not allow it to send large data files across the network [4].

The problem with RF is that its capacity is diminishing, meaning the radio spectrum is being filled, and it gets even harder to find the capabilities to make provision for the demand for wireless data transmissions. The radio frequencies are getting higher while the interferences become more problematic. These waves use a substantial amount of power, which results in the technology not being significantly efficient. It is important also to look at the cost of using this technology. Radio frequency components are very expensive which means the technology is costly.

The benefits of solving this problem will be the VLC technology that will ensure that all the problems stated are dealt with accordingly. Addressing these issues will ensure a technology that has a wide spectrum that can be used.

The technology is efficient because illumination and transmission occur simultaneously. There is guaranteed security because light does not penetrate through walls and it is safer for humans since visible light does not emit EMI. VLC can also transmit data at a higher rate than technologies that exist today.

Some technologies like infrared are used for point-to-point connection and VLC has many applications, from illumination, to cars using the LEDs to communicate with each other and from hospitals, to aircrafts. This technology could be very beneficial in many ways, such as when a home security is to be built using VLC. This technology is fairly new, so perpetrators

are unfamiliar with it, unlike with the current security systems that are well known. The security system has the ability to mislead criminals because it appears as a normal lighting system.

In this paper, we place our attention and proposal of designing a security system based on the technology of VLC where the intruders cannot be aware of such technology and this to give the house owners time to take the necessary measurements for the sake of safety and security of the residence.

The rest of this paper is organized as follows. In Section II, we present the communication system used in the design. Section III discusses the obtained results and the conclusion is given in Section IV.

II. COMMUNICATION SYSTEM DESCRIPTION

When dealing with visible light communication, it is important to take note of the components that form the system. There is a transmitter where the information is transmitted from. The channel is the light rays in which the information travels through, and there is a receiver where the information is received.

A. VLC Transmitter

Light emitting diodes are the main components of the transmitter. The transmitter contains an information source which generates the signal, it also has mechanisms for line coding and channel coding for forward error correction, the system also has a modulator, an LED driver circuit and the LED used for communication [3]. This transmitter is not like any other conventional transmitter, it has to act as a communication transmitter and it should also be used for illumination, these two requirements have to be considered. When modulating the data on the LED, the bandwidth of modulation has to be taken into consideration.

The data rate using LEDs is limited to tens of megahertz, the communication technology is able to use low data rate applications such as sending a text message [6]. The run length limited (RLL) line coding is used when avoiding long runs of ones and zeros. This long run can cause flickering of the light source which can cause damage to the eyes. The flickering can also cause data recovery detection problems [3]. This means that the modulation has to take place quick enough for the human eye not to perceive the on-off switching of the LED.

B. LED Characteristics

When incorporating visible light communication into the lighting system, it is ideal to use white light. White light LED come in two different categories, the first type consists of a blue LED that has a layer of phosphor on top. The phosphor absorbs the blue light partially and produces a yellow light, the blue and yellow light result in a white light being emitted. The second type is a combination of red, green and blue lights, which produce the white light [7].

C. On-Off Keying Modulation

OOK modulation is the simplest modulation scheme which uses voltage levels 0 or 1. It is a special case of amplitude shift keying (ASK). This means the light source is either turned on or off, which represent 1 and 0 respectively. When a zero is being transmitted, it does not necessarily mean the light is completely off, it simply means that data is being transmitted at low light intensity [8].

D. VLC Channel

The VLC channel is the medium between the transmitter and receiver. The medium is the light rays emitted by the LED. The channel is characterized to transmit the carrier signal to the receiver, through the light rays. Factors such as attenuation, noise and interference influence the channel. Channels can be classified into two types, which is the single channel with one LED and one phototransistor, and a multichannel with multiple LEDs and a phototransistor made up of more than one detector [2].

E. VLC Receiver

The phototransistor is the main component in the receiver. There are other optical components such as the optical filter and concentrator, the amplifier, the phototransistor and the circuit for signal recovery. Sunlight and other illuminations can interfere with the VLC system; it is important to have an optical filter to reduce the noise in the recovered signal. There are photodiodes that are good with responsivity to visible light. One can use the silicon p-type-insulator-n-type photodiode or the silicon avalanche photodiode.

The advantage of VLC technology is that LEDs are used for illumination and communication simultaneously, and this presents economic benefits, which makes it cost effective. The data transmitting diodes can replace fluorescent lamps and incandescent bulbs because of their characteristics of being mercury free, fast switching, efficient, and they have a long lifetime. Another advantage is that visible light does not cause electromagnetic interference (EMI). VLC can be used safely in airplanes and hospitals, where EMI is restricted.

Light does not penetrate through walls, so the data transmission will be secure and there will not be a chance of eavesdropping or hacking. The technology poses no health risks and it is environmentally friendly because the visible spectrum is used.

Figure 1 below illustrates the transceiver circuit that was built in the project. The circuit on the left represented the transmitter, and the circuit on the right represented the receiver. The transmitter was comprised of a single LED that transmitted a modulated pulse signal to the receiver, which comprised of a single phototransistor.

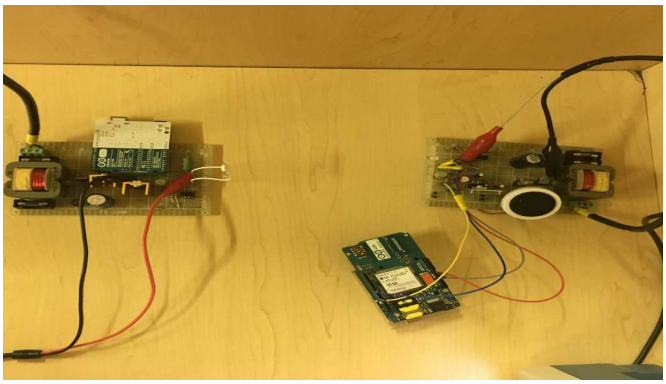

Figure 1: Experimental Transceiver Setup

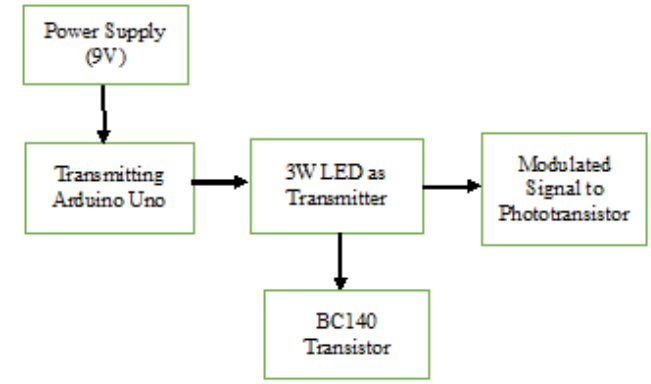

Figure 2: Transmitter Design Block Diagram

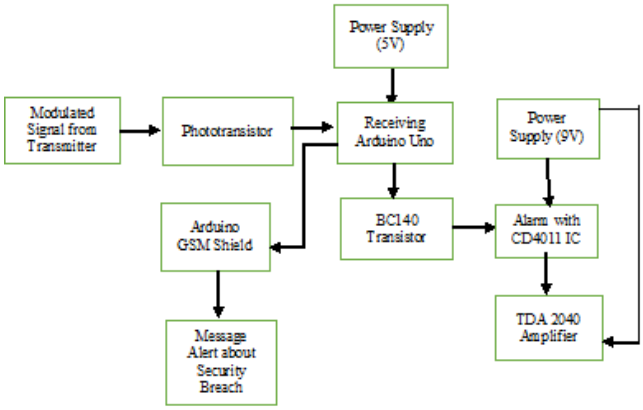

Figure 3: Receiver Design Block Diagram

Figures 2 and 3 show block diagrams for the transmitter and receiver.

III. RESULTS AND DISCUSSION

In this section, we report and analyze the obtained results from our proposed and designed circuit for our home security VLC. The results shown below illustrate the transmitter and receiver functionality test results, the distance test results, angle test results, and the GSM and alarm functionality results.

In Figure 4, the tests were conducted at a maximum distance of 30 cm. Observations were made in the results and they showed that the system was functional. The transmitter transmitted a pulse signal through light to the receiver, where the pulse was detected. When the communication between the transmitter and the receiver was interrupted, the receiver showed a straight line in the image on the right hand side, which was expected. There should be no signal detected when the transmission is interrupted.

In Figures 5 and 6, the results of the distance and angle tests showed that the signal weakened or diminished with an increase in distance and angle. The observations showed that the system was consistent with the expected theoretical results.

Figure 5 illustrated that with an increasing distance, the voltage decreased. At a maximum of 300 mm, the voltage was the lowest, which meant that the strength of the signal was weakening with an increased distance. The same could be said about the increasing angle in Figure 6. The detected signal weakened and there was a decrease in voltage with an increasing angle away from the receiver.

The GSM shield and the alarm circuit were tested. The results in Figure 7 showed that the GSM shield functioned properly. When the communication between the transmitter and receiver was interrupted, the alarm was activated, and a message was sent to the user of the security system.

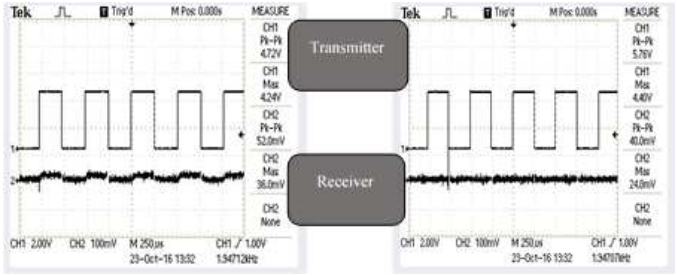

Figure 4: Transceiver Functionality Test Results

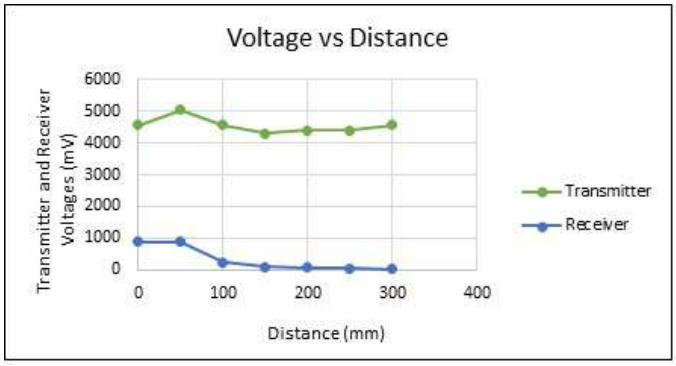

Figure 5: Distance Test Results

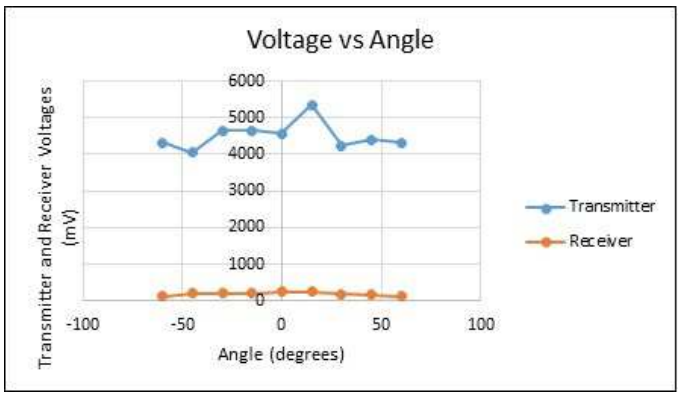

Figure 6: Angle Test Results

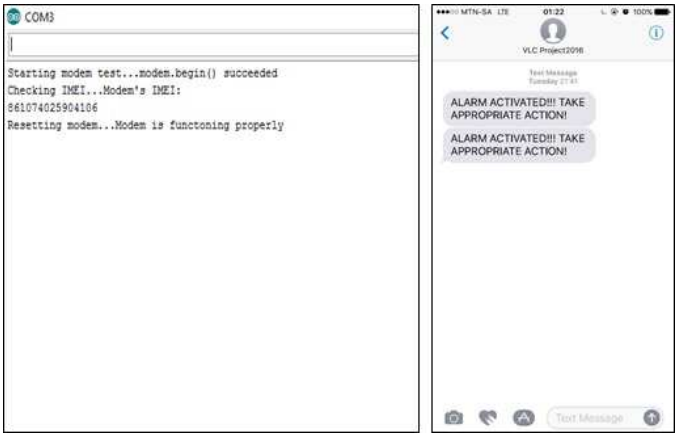

Figure 7: GSM Shield and Alarm Functionality Test

Current security systems use motion detection with infrared communication and/or camera technology. The motion detection security system implemented in this research however uses light emitting diodes for both communication and illumination which is an advantage over the infrared and camera systems, these systems only have a communication aspect. The LED can be dimmed during the day and be at full brightness at night, when the light is dimmed, information is still being transmitted through the light. The system appears as a normal lighting system, this is advantageous because the intruder is used to seeing cameras, infrared motion detection systems and motion detector lights. When they approach a house that uses the VLC system, they will not be aware that there is a security system in place. The customer can feel more secured knowing this security system's capability. The more the system satisfies the customers' security needs, the customer will be more likely to refer the system to other people.

IV. Conclusion

The main objective of the research was to detect motion for home security using VLC. It was found in the tests conducted that, the transmitter and receiver were functional. The transmitter sent a pulse signal and the receiver detected the same pulse that was transmitted.

When motion was detected, the receiver did not detect the pulse that was transmitted, hence the straight line in the image on the right hand side in Figure 4

During the distance test it was observed that, with an increasing distance, there was a decrease in voltage, as seen in the graph in Figure 5.

During the angle test it was observed that, with an increasing angle, there was a decrease in voltage, as seen in the graph in Figure 6.

Figure 7 illustrates the functionality of the GSM shield and the alarm. The objective of the project was achieved. A motion detection home security system using visible light communications was built, and it proved to be functional. When the alarm was activated, a text message was sent to the user to notify them of a breach in security.

After the tests were conducted and the system was understood, it can be said that the motion detection home security using visible light communications is advantageous over the camera systems, infrared motion detection security systems and the light motion detector security systems that are currently commonly used.

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